

METHOD AND APPARATUS FOR INTERLEAVING MULTIPLE FRAMES OF DATA

5

TECHNICAL FIELD

This invention relates in general to the field of radio communications and more specifically to a method and apparatus for interleaving multiple frames of data.

10

BACKGROUND

In modern Direct Sequence Spread Spectrum (DSSS) modulators, data is convolutionally or turbo encoded, punctured, and interleaved prior to transmission. The Telecommunication Industry Association (TIA) IS-2000 standard outlines two interleaving requirements, one for backward compatibility with previous DSSS standards, and a second for newly introduced data rates and channel structures. The IS-2000 standard also requires puncturing of 20 millisecond (ms) frames with 5ms or 10ms frames.

“Puncturing” in the current context means replacing some portion of a 20ms frame with a shorter length (5ms or 10ms) frame. The portion may be any one of the four possible quadrants of a 20ms frame (5ms puncturing), or one of either the first or the second halves of a 20ms frame (10ms puncturing). In either case, more than one interleaver configuration must be employed (one for the original 20ms frame and one for the punctured frame). The interleaving mechanism for IS-2000 is given in the standard as

a read-address generator, implying the function would be implemented at the output or “read” side of the interleaver memory. Doing this would cause the output address control circuitry to be unnecessarily complex since one interleaving engine with a dedicated memory per data channel would be necessary to accomplish the puncturing.

5 IS95 interleaver designs include a two-stage approach for interleaving data. First a write function is used to place data in memory, then a specialized read function is used to access the data for transmission. A traditional modulator 100 configuration is shown in FIG. 1. A write address generator 102 is used to place data in memory 106, while a read address generator 104 is used to access data from memory 106.

10 The modulator architecture shown in FIG. 1 may work for the IS-2000 standard, but substantial control circuitry will be required to orchestrate the puncturing of sub-20ms frames on the output side of the memory. The IS-2000 complexity is increased because multiple interleaver engines are needed to build individual channels when puncturing of 20msec frames occurs. A need thus exists in the art for a method and apparatus that can
15 handle transmission data in the modulator and that can support a variety of interleaver structures and perform efficient puncturing of frames.

BRIEF DESCRIPTION OF THE DRAWINGS

20 The features of the present invention, which are believed to be novel, are set forth with particularity in the appended claims. The invention, may best be understood by reference to the following description, taken in conjunction with the accompanying

drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIG. 1 shows a prior art modulator.

FIGs 2A and 2B highlight the interleaving method used in the IS-2000 standard
5 for IS95A/B interleaving.

FIG. 3 shows an IS-95 interleaving in accordance with the invention.

FIG. 4 shows the mapping from 'input-based interleaving' to 'output-based interleaving' in accordance with the invention.

FIG. 5 shows an IS-2000 bit-exact interleaving implementation in accordance with
10 the invention.

FIG. 6 shows illustrates a memory addressing technique in accordance with the invention.

FIG. 7 shows a modulator in accordance with the present invention.

15 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

While the specification concludes with claims defining the features of the invention that are regarded as novel, it is believed that the invention will be better understood from a consideration of the following description in conjunction with the drawing figures, in which like reference numerals are carried forward.

20 The present invention provides for a seamless solution to the punctured frame requirement of the IS-2000 standard while providing for a simplified hardware flow for interleaving. The invention also provides for a flexible method for allocating multiple

reverse link channels, each of programmable size within a single interleaver memory. A PN index in the addressing of the interleaver memory for the transfer of data to the spreading/filtering unit is utilized which allows for leveraging the PN index and thereby simplifying the overall design.

5 All interleaving is done on the input side of the memory by “inverting” the process in the case of IS-2000 interleaving, and combining the output portion within the input portion, in the case of the IS-95 standard interleaving. IS-95 interleaving is defined by two stages: write by column, and read by row. With the current invention, both functions are performed at the same time, i.e. before being written to the interleaver
10 memory. With inverse interleaving, the entire 20ms frame is built in the first pass, then portions of the frame are directly replaced by simply changing the write-address offset and over-writing the appropriate area of interleaver memory using a different set of interleaving parameters. For example, in the case of puncturing a 5ms frame into a 20ms frame, the 20ms frame data is first interleaved and deposited in memory, after which the
15 5ms frame is interleaved over the appropriate quadrant within the 20ms frame within the memory. Thus, the entire buffer may be read out of the interleaver memory sequentially.

Simplified Interleaving

20 The interleaving function is simplified in accordance with the invention by consolidating the interleaving at the input side of the interleaver memory as will be discussed below. By doing so, data read from the interleaver memory may be accessed

sequentially. The prior art of the IS-2000 standard indicates two interleaver structures in which interleaving is done when reading from the interleaver memory. Both of these interleaver structures need to be inverted to perform the complete interleaving function at the input side of the memory. The first interleaver described in the standard is required
 5 for backward compatibility with IS-95 systems, while the second meets the requirements of the IS-2000 standard. The following sections offer a detailed description of the inverse interleaving and output addressing.

IS-95 interleaver (and RC1 & RC2 of the IS-2000 standard)

10

As shown in FIGs 2A and 2B, the prior art interleaving method defined in the IS-2000 standard indicates writing data into a 32X18-memory array by column and then reading out from the array by row. In the standard, the read-row order is determined by swapping certain bits in a 5-bit sequential address as follows:

15

(1). For full rate (9600 or 14400 bps), there is no transformation. The address is applied sequentially: $A_4A_3A_2A_1A_0$

(2). For $\frac{1}{2}$ rate (4800 or 7200 bps): $A_4A_3A_2A_0A_1$

(3). For $\frac{1}{4}$ rate (2400 or 3600 bps): $A_4A_3A_1A_0A_2$

20 (4). For $\frac{1}{8}$ rate (1200 or 1800 bps): $A_4A_2A_1A_0A_3$

(5). For Access Channel: $A_0A_1A_2A_3A_4$

The objective of the interleaving is to accept input data sequentially in time, place it into the position in memory from which it should be read using a sequential addressing scheme. In other words, both write and read functions of the interleaver are merged into one function. FIG. 2A shows the mapping process of input data (by row) to its final read-
 5 ordered position in memory, if the memory were configured the way the algorithm is defined in the standard (32x18). The first column is the row read order given by the standard. The second column is the input order of the data, and the third is the new write address required to avoid read-row randomization (i.e., when reading from the interleaver memory).

10 For example, in the 2400/3600 bps example, looking at the “Data Input Order” column, it is shown that the 0th input is read out first based on the standard algorithm (generic read order column). Therefore, it should be stored in New Write Address = “0”. The 1st input is read out 3rd so goes in New Write Address = “2”. The 2nd input is read out second so belongs in New Write Address = ‘1’, and so forth.

15 Since the original algorithm states that data is written in 32-bit columns from top to bottom, as shown in FIG. 2B in table 202, and read out by interleaved row, it can be shown that the mapping process in FIG. 2A succeeds in re-ordering the rows so they can be read out sequentially yet still be interleaved properly. A re-mapping function is applied to a sequential input address generator in order to select the appropriate bit for
 20 each 32-bit input column.

Having re-mapped the position of the input data within each column denoted in table 202 as TN, we now have a 32x18 bit matrix of data. It is desirable to provide one

six-bit value at each address in memory so as to simplify the retrieval of data by the output addressing mechanism (since six symbols are used every 256 PN chips). In order to accomplish this, each 18-bit word is remapped into three six-bit words, each at its own location in memory.

5 It is shown in table 202 that each 32-bit input in the original matrix must be further mapped into the format shown in table 204. Since the input data has already been mapped into read order, we now only have to determine the address location in memory that each value must be placed based on where it appears in the 32x18 matrix.

Each 18-bit word needs to be re-positioned into three six-bit words, each at its
10 own location address. Inspection of the two matrices reveals the following relationship:

$$\text{If } TN = 0 \sim 5, A_n = A_{or} * 3;$$

$$\text{If } TN = 6 \sim 11, A_n = [A_{or} * 3] + 1; \quad (\text{Equation 1})$$

$$\text{If } TN = 12 \sim 17, A_n = [A_{or} * 3] + 2;$$

This observation means the remapped rows of FIG. 2A are further mapped as shown in
15 equation 1 above. The implementation of the IS-95 interleaver shown in FIG. 3, includes a modulo 6 counter which indexes through the groups of six 32-bit columns. It also includes a multiply-by-3 (shift & add) block, and a modulo 3 result which is incremented after each 32x6 group has completed, which satisfies the offset shown in equation 1 above.

20

IS-2000 Interleaver (and RC3~6 of IS-2000)

The IS-2000 standard states that “the symbols input to the interleaver are written sequentially at addresses 0, to the block size (N) minus 1. Interleaved symbols are read out in a permuted order with the i-th symbol being read from address A_i , as follows:

$$A_i = 2^m(i \bmod J) + \text{BRO}_m\left(\left\lfloor \frac{i}{J} \right\rfloor\right) \quad (\text{Equation 2})$$

- 5 where $i = 0$ to $N - 1$, $\lfloor x \rfloor$ indicates the largest integer less than or equal to x , and $\text{BRO}_m(y)$ indicates the bit-reversed m -bit value of y .

In FIG. 4, it is shown how equation 2 works. The left column of FIG. 4, shows the linearly ordered input bits to the interleaver and the right column shows the linearly ordered output bits. FIG. 4 illustrates how linearly ordered bits that are received are store
 10 in such a way that they can be read linearly. FIG.4 also shows that input bit addresses can be grouped by bunches of 2^m consecutive values and that output bit addresses will receive their inputs from groups of addresses in a sequence that repeats every J bits, hence modulo J . FIG. 4 however does not indicate which address inside a group is actually sent to the output column. This is the tricky part of the algorithm where the Bit Reversal
 15 comes into play.

Look at i within sets of J values, i.e. we apply an integer division of i by J ; there exist two unique integers k and p such that:

$$i = kJ + p \quad \text{with } 0 \leq p \leq J-1 \quad \text{and } k \geq 0 \quad (\text{Equation 3})$$

- 20 Substituting Equation 3 into the first part of Equation 2 results in:

$$A_i = 2^m((kJ + p) \bmod J) + \text{BRO}_m\left(\left\lfloor \frac{i}{J} \right\rfloor\right)$$

$$A_i = (2^m \times p) + \text{BRO}_m \left(\left\lfloor \frac{i}{J} \right\rfloor \right) \quad (\text{Equation 4})$$

By construction of the BRO_m function, we have:

$$0 \leq \text{BRO}_m(y) \leq 2^m - 1 \quad (\text{Equation 5})$$

5

since BRO_m is an m -bit number. Combining Equations 4 and 5 and keeping in mind that p is positive, leads to the conclusion that p is the quotient of the integer (Euclidean) division of A_i by 2^m and that $\text{BRO}_m \left(\left\lfloor \frac{i}{J} \right\rfloor \right)$ is the remainder.

We may already assert than an incoming bit in the A_i -th position will be read in the i -th position such that:

10

$$i = kJ + p \quad \text{with} \quad p = \left\lfloor \frac{A_i}{2^m} \right\rfloor \quad (\text{Equation 6})$$

but we do not know how to process k yet.

Substituting the value of i in Equation 3, into Equation 4 leads to:

$$A_i = (2^m \times p) + \text{BRO}_m \left(\left\lfloor \frac{(kJ + p)}{J} \right\rfloor \right) \quad (\text{Equation 7})$$

15

The definition of k and p of Equation 3 implies that:

$$\left\lfloor \frac{(kJ + p)}{J} \right\rfloor = k \quad (\text{Equation 8})$$

From Equations 7 and 8 we get:

$$A_i = (2^m \times p) + \text{BRO}_m(k) \quad (\text{Equation 9})$$

Now, let q be the remainder of the division of A_i by 2^m :

$$5 \quad q = A_i \bmod 2^m. \quad (\text{Equation 10})$$

It has been shown that:

$$q = \text{BRO}_m\left(\left\lfloor \frac{i}{J} \right\rfloor\right) = \text{BRO}_m(k) \quad (\text{Equation 11})$$

10 The Bit Reversal function has the obvious property that applied twice in a row it is equivalent to zero; hence:

$$\text{BRO}_m(q) = \text{BRO}_m[\text{BRO}_m(k)] = k \quad (\text{Equation 12})$$

We have now come to the final conclusion, that the A_i -th input bit goes to the i -th address of the output table such that:

15

$$i = kJ + p \quad \text{with } p = \left\lfloor \frac{A_i}{2^m} \right\rfloor \quad \text{and } k = \text{BRO}_m(A_i \bmod 2^m) \quad (\text{Equation 13})$$

It is worth mentioning that the J value is chosen in the IS-2000 standard to be of the form

20 $J = 3 \times 2^n$, where n is an integer. This makes the multiplication by J relatively easy to achieve.

In FIG. 5, there is shown the hardware implementation of the inverse interleaver of IS-2000. The write address I , is given as:

$$I = kJ + P$$

where: J can be defined as $3 \cdot 2^n$ or $9 \cdot 2^n$ (i.e., as determined in tables 2.1.3.1.7-1 of the IS-2000 standard, J can be decomposed in this manner); $P = A_i / 2^m$ and A_i is the requested address; $k = \text{BROm}(A_i \bmod 2^m)$; $\text{BROm}(y)$ = bit-reversed m -LSBs of y . The assignable parameters are: INTL_M which is used for m ; INTL_L is used as the 3 or 9 multiplier in J above; and INTL_N is used for n .

Use of offset addressing of a single contiguous interleaver memory provides the flexibility to engage different numbers of channels while easily configuring them for different rates. This flexibility allows the most efficient use of data path bandwidth since the memory may be used for multiple channels of varying data rates, or it may be consumed by a single high-data-rate channel. Additional flexibility can be leveraged since both input and output address offsets are applied allowing any channel to be assigned to any region within the interleaver memory. This provides for a simplified yet maximally flexible method for allocating multiple reverse link channels, each of programmable size within a single interleaver memory.

In the present invention, utilization of reverse link timing reference in the addressing of the interleaver memory for the transfer of data to the spreading/filtering unit. Output data is ultimately Walsh covered (RC3~6) or Walsh modulated (RC1~2) and PN-spread prior to transmission by a Walsh function block and PN sequence block

respectively. An advantage can be gained if a simple counter tied to reverse link timing can be leveraged to address the interleaver memory.

Typical modulator front-ends require the interleaver memory to be tightly coupled to the interleaving function. For example, the IS-95A/B standards imply a two-stage interleaving process (write by row, read by column) that complicates the option of leveraging the counter mentioned above for output addressing. In addition, due to the punctured frame requirement of the IS-2000 standard, typical architectures will not be able to take advantage of the counter without first applying complicated manipulations to adjust for punctured frames.

FIG. 6 illustrates the method of output addressing of the memory in accordance with one aspect of the invention. Utilization of a counter tied to reverse link timing is possible because modulation data duration is given in terms of a finite number of pseudonoise (PN) chips, or 'Chips Per Modulation Symbol' (CPMS). Depending on the CPMS requirement for a particular frame of data, the addressing can be generated by simply selecting the appropriate range of the counter. Note that the counter changes state at the chip rate, meaning that if we were looking for a CPMS of four, we would select the lowest bit of addressing to correspond to the third bit of the counter: Address $[n:0] = \text{counter}[(n+2):2]$.

As described above, the present invention provides for an extremely streamlined approach to achieving both methods of interleaving as defined in the IS-2000 standard, while meeting the complex requirement of frame puncturing in a straightforward manner. Since output addressing is directly driven by the PN index or a counter locked to the

reverse link timing, it is a simple matter of range selection to achieve all possible configurations required in the IS-2000 standard.

While the prior art requires the use of complex counters, state machines, and terminal count parameters, to achieve the puncturing of sub-20ms frames. It is easily accomplished via the use of a single contiguous memory and interleaver engine that resides on the input side of the interleaver memory as provided by the present invention. The overall structure of the approach taken in this invention affords maximum flexibility within a simplified architecture.

While the preferred embodiments of the invention have been illustrated and described, it will be clear that the invention is not so limited. Numerous modifications, changes, variations, substitutions and equivalents will occur to those skilled in the art without departing from the spirit and scope of the present invention as defined by the appended claims.

What is claimed is: